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Comparative analysis of conventional optimization techniques with Artificial Neural Network (ANN) and Response Surface Methodology (RSM) models for extracting oil from *Chrysophyllum albidum (C. albidum)* seed for biodiesel production

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To Cite:
Keke M, Chidiebere OF, Emoefe RID, Adepoju TF. Comparative analysis of conventional optimization techniques with Artificial Neural Network (ANN) and Response Surface Methodology (RSM) models for extracting oil from *Chrysophyllum albidum (C. albidum)* seed for biodiesel production. *Discovery* 2024; 60: e8d1404
doi: https://doi.org/10.54905/disssi.v60i334.e8d1404

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Peer-Review History
Received: 28 November 2023
Reviewed & Revised: 02/December/2023 to 06/February/2024
Accepted: 10 February 2024
Published: 14 February 2024

Peer-Review Model
External peer-review was done through double-blind method.

Discovery
pISSN 2278–5469; eISSN 2278–5450

DISCOVERY SCIENTIFIC SOCIETY

ABSTRACT

This study aimed to optimize the process of oil extraction from *Chrysophyllum albidum (C. albidum)* seeds. The research involved quality assessment, seed preparation, Soxhlet extraction apparatus with n-hexane employed as a solvent. The utilization of the Box-Behnken design involved implementing a series of three-level factors, leading to a total of 17 experimental runs aimed at attaining the optimal oil extraction. The optimal conditions for oil extraction were identified as a 50g sample, 250ml solvent, and 40 minutes, resulting in a 3.0896% (w/w) yield, the lowest oil yield was 1.5931%(w/w) deviating from projections by response surface methodology (RSM) and artificial neural network (ANN). The oil exhibited a reddish-brown color and various physiochemical properties. The current study did not consider alternative optimization methods such as particle swarm optimization and genetic algorithms when assessing optimal sites. Future research could explore these specific areas. After the optimization methods were validated, the investigation reached the determination that the oil is unsuitable for consumption and possesses significant value within the manufacturing sector.

Keywords: *Artificial Neural Network (ANN), Response Surface Methodology (RSM), Chrysophyllum albidum, Oil yield, Analysis of variance (ANOVA) and Optimization.*

1. INTRODUCTION

The *Chrysophyllum albidum,* commonly known as the African star apple, is a tree native to African forests. It is classified as a member of the Sapotaceae family, which encompasses more than 800 species and represents a significant portion of the tree order. The aforementioned tree exhibits significant promise for the purposes of agro-forestry and plantation development, respectively potential (Ehiagbonare et al., 2008). The fruit possesses significant significance due to its wide range of applications in industries, medicine, and culinary practices. A significant proportion of African star apples are cultivated mostly inside the southern region of Benin in Nigeria. While it has the ability to endure temperatures as high as 34 degrees Celsius, this organism often exhibits optimal growth in geographical areas characterized by mean annual temperatures ranging from 18 to 28 degrees Celsius. The species has a range of adaptability to precipitation levels, with a minimum threshold of 1,100 mm and an upper limit of 2,800 mm.

However, it demonstrates optimal growth and development when exposed to higher amounts of rainfall. The organism exhibits the capacity to endure a pH range spanning from 5 to 7, however it is commonly cultivated in a deep, rich loamy soil with a pH range of 5 to 6.5. The African star apple, also known as Agbalumo in Yoruba, Utieagadava in Urhobo, Agwaluma in Hausa, Udara in Igbo, Ibibio, and Efik, as well as Ehya in Igala, is a variety of berry that is very important economically in tropical Africa. This is attributed to its various industrial and dietary applications, along with its multiple health benefits. The aforementioned benefits encompass reduced calorie and saturated fat content, a substantial amount of dietary fibre, and a tenfold higher concentration of ascorbic acid compared to other fruits within the citrus family. According to a specific study, Agbalumo has the potential to be beneficial in the prevention and treatment of cardiovascular problems.

The pulp of the African star apple fruit is a rich source of iron, vitamin C, natural flavorings, and raw materials that can be utilized in the industrial sector. The study conducted by Duyilemi and Lawal, (2009) presents the findings of the composition of *Chrysophyllum albidum*, which encompasses a diverse array of compounds such as tannins, flavonoids, proteins, carbohydrates, anthraquinones, cardiac glycosides, and resins. The isolation of eleagrine, together with skatole, tetrahydro-2-methyl harman, and other components, has been found to contribute significantly to the antibacterial properties of the plant (Idown et al., 2009). Numerous hypotheses posit that the chemicals present in the cotyledon of *Chrysophyllum albidum* seeds may possess qualities that can potentially mitigate hyperglycemia and hypolipidemia. The use of different parts of the plant, such as the roots, bark, and leaves, has been observed in diverse therapeutic applications aimed at treating ailments such as coughs, yellow fever, and hypertension, among others.

During the period spanning from December to March (Amusa et al., 2003). *Chrysophyllum albidum* can be found in both rural and urban regions of Nigeria. The substance in question is widely acknowledged as a natural reservoir of antioxidants, which have the potential to mitigate the onset of diseases associated with oxidative stress by effectively neutralizing free radicals (Amusa et al., 2003). The seeds of African star apple, typically discarded as inedible waste, have lately been found to possess economic value. The aforementioned discovery has demonstrated a reduction in environmental pollutants and the promotion of a more sustainable and ecologically sound environment (Emmanuel et al., 2012). The seeds, characterized by their tough outer shell, radial arrangement, and dark brown coloration, are often located within the fruit of the plant (Abel et al., 2020; Adekanmi and Olowofoyeku, 2020).

The tree exhibits an annual fruiting pattern, wherein the fruits undergo a colour transformation from a greenish hue to a yellow shade when reaching maturity (Agunbiade and Adewole, 2014). The increasing demand for oil in both the industry and private sectors has prompted a search for new and less utilized seeds to complement traditional oil sources (Akubugwo et al., 2007). Over the years, several groups of researchers have examined at the ways process variables affect the output of oils (Goziya et al., 2022). Oil extraction from a variety of oilseeds has been investigated employing kinetics and thermodynamics such as *jatropha curcas* Amin et al., (2010), Santos et al., (2015), moringa seed oil Olakunle and Umar, (2019), pumpkin seed Nwabanne, (2012), *asterminia catappa L* (Menkiti et al., 2015).

Plant-derived oil has the potential to be employed in the production of many products such as bio-oils, bio-lubricants, cosmetics, pharmaceuticals, and several other goods (Abel et al., 2020). Various methods can be employed for the extraction of oil from oilseeds, encompassing mechanical pressing, pressurised solvent extraction, Soxhlet extraction, ultrasonic extraction, aqueous enzymatic oil extraction (AEOE), and extraction by agitation and shaking necessary. In addition, there exists a diverse array of methodologies that can be employed to simulate and enhance experimental data pertaining to the process of oil extraction. Several methodologies, such as

Response Surface Methodology (RSM), Artificial Neural Network (ANN) design, Arena, Mathlab, and Minitab Response Surface (MRS), have been identified as examples (Adepoju and Eyibio, 2016).

2. METHODS

Oil Extraction Procedures

The oil derived from the seeds of *C. albidum* (Figure 1) was obtained from Nung-Ita village, located in the Oruk-Anam municipality of Akwa-Ibom state. The oilseed underwent a series of procedures which including the washing, dehulling, and elimination of husks and contaminants. Following this, the material was subjected to a sun-drying process lasting five days until it had a uniform weight. Subsequently, the material was pulverized using a blender.

(a) (b) (c)

Figure 1 (a) *Chrysophyllum albidum* fruit, (b) *Chrysophyllum albidum* seeds, (c) Powdered *Chrysophyllum albidum* seeds

The Soxhlet device was utilised to house a muslin sack containing powdered oilseed, which was placed into the thimble. A heating mantle was employed to provide thermal energy, thereby sustaining the solvent (n-hexane) at a temperature slightly lower than its boiling point. The heating apparatus was positioned above a flask with a circular bottom, which contained a predetermined quantity of the solvent. Upon the conclusion of the procedure, the solvent was collected, and the mass of the resultant oil was determined. The oil yield estimation was computed by utilizing equation 1.

$$CLOY = \frac{weight\ of\ extracted\ oil\ (g)}{weight\ of\ sample\ weight\ (g)} \quad (1)$$

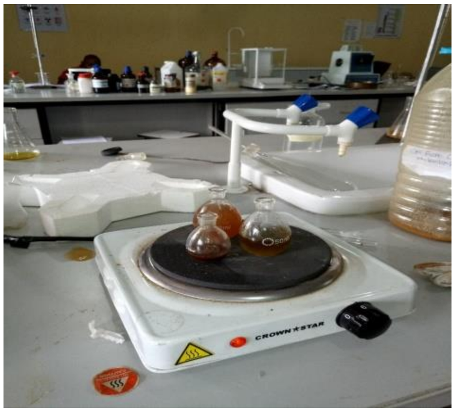
The n-hexane contained in the soxhlet extraction flask was subjected to heating using a water bath labelled with the serial number DK-501A, as part of the oil extraction procedure. The water bath is furnished with a temperature control range that ensures a deviation of only 0.5 degrees from the designated value. The surplus n-hexane residue that remained following the oil extraction process was eliminated through evaporation. This was achieved utilizing a PEC Medical USA 500 x 4 four-phase heating mantle, which has the capacity to measure temperatures up to 150 degrees Celsius.

The total weight of chemicals, oil, and other materials utilized in this study was determined using a digital weighing balance known as the S. Mettler FA2104, which has a maximum capacity of 210 g and an error margin of 0.001 g. To ascertain the moisture content of the extracted oil, we utilized a heating and drying oven from the DHG model, continuing until a constant weight was achieved. The sole modification needed to transform any of the employed chemicals into the required standard reagents was to add moisture. All of the chemicals utilized were of the suitable quality as seen in (Figure 2).

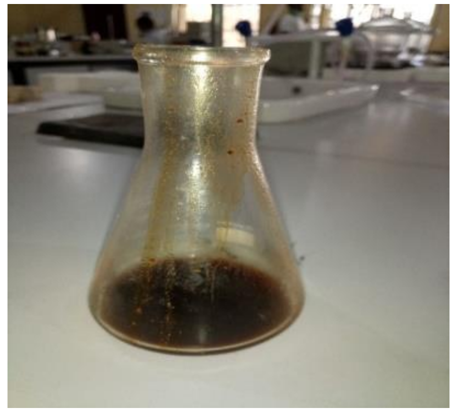
***Chysophyllum albidum* Extracted Oil Properties**

The essential factors, such as viscosity, API gravity, and oil specific gravity, were considered during the analysis of the oil's characteristics. Standard methods were employed, as outlined in references (EN-14214 and ASTM-D6751). Furthermore, the oil's viscosity was measured using an NDJ5S viscometer, while its specific gravity was determined by comparing its weight to the weight of an equivalent volume of water. Subsequently, the second formula below was applied to calculate the oil's API gravity.

$$\mathrm{API} = \frac{141.5}{\mathrm{Specific\ gravity\ @\ 15^{o}c}} - 131.5 \quad (2)$$



(a)



(b)

Figure 2 (a) Heating mantle (b) Extracted C.albidum oil

Experimental procedures for *chysophyllum albidum* oil extraction

Experimental Design for Oil Extraction

Response Surface Methodology (RSM) and Artificial Neural Network (ANN) were both used in this study as experimental designs for modeling and optimization. In particular, the Box-Behnken experimental design was used to streamline the RSM-based extraction of C. albidum seed oil. Three essential variables were taken into consideration in order to facilitate the modeling process of the experimental design. Table 1.1a presented the coded representation of the factors under examination in this research, whereas Table 1.1b demonstrated that the BoxBehnken design produced 17 experimental runs. Key parameters, including extraction time (in minutes), sample weight (in grams), and solvent volume (in milliliters), were carefully considered. Subsequently, a set of experimental data for an artificial neural network (ANN) was refined and acquired using the identical method, with a subsequent comparison of the results.

Table 1.1a Factors and their coded factor levels for Box-Behnken design

Factor	Symbol	Coded	Factor	Levels
		-1	0	1
C.albium weight (CAW) *(g)*	X1	40	50	60
Solvent volume (SV) (ml)	X2	150	200	250
Extraction time (ET) (min)	X3	40	55	70

Table 1.1b Experimenting with three independent factors Using the Box-Behnken Method

Std. Run	X1	X2	X3
1	-1	-1	0
2	1	-1	0
3	-1	1	0
4	1	1	0
5	-1	0	-1
6	1	0	-1
7	-1	0	1
8	1	0	1
9	0	-1	-1
10	0	1	-1
11	0	-1	1

12	0	1	1
13	0	0	0
14	0	0	0
15	0	0	0
16	0	0	0
17	0	0	0

Statistical Data Analysis

The data obtained from the *C. albidum* seed oil recovery processes will be subject to statistical analysis using response surface techniques. The objective of this analysis is to conform to the quadratic polynomial equation produced by Design-Expert software version 8.0.3.1. Multiple regression studies will be conducted in order to establish the link between the response variable and the independent factors, as well as to find the coefficients of the polynomial response model. The evaluation of the model's ability to accurately describe the data will be conducted by means of significance tests and analysis of variance (ANOVA). Below, you'll find some instances illustrating the fitted quadratic response model:

$$Y = a_0 + \sum_{i=1}^{k} a_i X_i + \sum_{i=1}^{k} a_{ii} X_i^2 + \sum_{i<j}^{k} a_{ij} X_i X_j + e \qquad (3)$$

Where:

Y's response factor (*C. albidum* oil yield), bo is the intercept value, bi (i = 1, 2, k) is the first-order model coefficient, bij is the interaction effect, and bii represents the quadratic coefficients of Xi. The random error is represented by the letter e.

3. RESULTS AND DISCUSSION

Optimization of the extracted Chrysophyllum albidum Seed Oil

Modeling and variables optimization by RSM

The results of the Box-Behnken experiments can be found in (Table 2). To determine the statistical significance of the models created, an analysis of variance (ANOVA) test was conducted, as shown in (Table 3a). To assess the model's goodness of fit, we relied on the coefficient of determination (R2), with a minimum value of 0.80 indicating an appropriate fit. The R2 (adjusted) value was 30%, while the regular coefficient of determination (R2) stood at 70%. For a summary of the ANOVA results related to the regression equation, please refer to (Table 3b). The lack of fit F-value, at 0.36, suggests that when compared to the pure error, the lack of fit is not notably significant. Nevertheless, the model has attained an F-value of 1.78. The statistical significance of the regression was assessed by calculating F and P values, utilizing both Fischer's and null-hypothesis tests. The F-value provides a measure of the overall model quality when all design factors are taken into account simultaneously. On the contrary, a P-value often serves as an indicator of the importance of a model term, without providing information regarding the directionality of the significance, whether positive or negative (Oyeniran et al., 2013).

A small P-value and F-value indicate a high level of statistical significance for the regression model, implying its substantial relevance. The findings of the statistical analysis are displayed in Table 3, which provides information on the regression coefficients, t-values, and p-values pertaining to the influences of linear, quadratic, and combination variables. In order to satisfy the requirements for statistical significance, it is necessary for the P-value to be within the range of 0.05, as outlined by Patel et al., (2016) standard. The results validate the importance of word B at a significance level of 0.0500. Furthermore, throughout the course of this inquiry, it was observed that the centre points exhibited orthogonality with respect to the other components in the model. This was determined by the analysis of the Variance Inflation Factor (VIF) and F-ratio estimations, which were conducted at a 95% confidence level (Table 4). Equation (4) represents the final equation of the Box-Behnken Design quadratic model in terms of coded factors. Top of Form

OY = 2.75 – 0.38X1 + 0.75X2 – 0.31X3 – 0.23X1X2 +0.39X1X3 + 0.067X2X3 – 0.059X12 + 0.29X22 – 0.051X32 (4)

Where OY is the Oil yield (%), X1 is the C.albidum weight (g), X2 is the Solvent volume (ml), and X3 is the Extraction time (minutes). Utilizing regression analysis on Equation 4, through the Design Expert software version 10.0.6.0 resulted in identifying the optimal combination of independent variable values for the extraction process. Based on the data presented in Table 2, it can be observed that the optimal oil yield was obtained by employing a sample mass of 50 grammes, a solvent volume of 250 milliliters, and

an extraction duration of 40 minutes. According to the initial prediction of the response surface methodology (RSM), the anticipated yield was 3.97%. Nevertheless, the RSM analysis suggested that modifying the parameters to a sample weight of 60 grammes, a solvent volume of 150 milliliters, and an extraction duration of 55 minutes might potentially result in a 2.07% deviation in the final result, represented as a weight percentage. The oil yield reached its minimum value of 1.5931% in terms of weight, as documented in the records.

Modeling and variables optimization by ANN

The extraction of *C. albidum* oil was reproduced using artificial neural networks (ANNs). ANNs are an algorithm-based learning system that can mimic the cognitive processing skills seen in the human brain. The study employed Neural Power version 2.5; a software component developed by CPC-X Software. The configuration parameters encompassed the specification of the neuron count within a solitary hidden layer, the selection of transfer functions for both the hidden and output layers (including sigmoid, hyperbolic tangent, Gaussian, linear, threshold linear, and bipolar linear functions), and the establishment of the optimal network architecture. These parameters were specifically determined for a single hidden layer. Furthermore, it should be noted that each Artificial Neural Network (ANN) underwent training using the conventional stopping condition of 100,000 iterations.

The data presented in Table 2 demonstrates that, among the range of factors examined, the highest oil yield achieved was 3.9228% (by weight). This result was obtained by employing a sample size of 50 grammes, a solvent volume of 250 milliliters, and an extraction duration of 40 minutes. The achieved response closely approximated the expected value of 3.9053% (by weight), as predicted by the Artificial Neural Network (ANN). In contrast, the minimum attainable oil yield was determined to be 1.5931% (by weight) using a sample weight of 60 grammes, a solvent volume of 150 milliliters, and an extraction duration of 55 minutes. Remarkably, the projected outcome generated by the Artificial Neural Network (ANN) yielded a weight percentage of 1.5932% under the given set of circumstances. Furthermore, the R-squared adjusted (R2 (adj)) value for the ANN model was determined to be 85.42%, while the coefficient of determination (R2) was notably higher at 92.42%.

Table 2 Experimental Data for Oil Yield, Predicted Oil Yield and Residual values

Std. Run	X1	X2	X3	Oil yield % (w/w)	Predicted		Residual	
					RSM	ANN	RSM	ANN
1	-1	-1	0	2.1767	2.38	2.0722	-0.20	0.10457
2	1	-1	0	1.5931	2.07	1.5932	-0.48	2.3571E-5
3	-1	1	0	4.8065	4.33	4.8048	0.48	0.0016794
4	1	1	0	3.3173	3.12	3.3237	0.20	0.0064103
5	-1	0	-1	3.2827	3.71	3.3006	-0.43	0.017823
6	1	0	-1	2.018	2.17	2.018	-0.16	1.5145E-6
7	-1	0	1	2.4772	2.32	2.4726	0.16	0.0046234
8	1	0	1	2.769	2.34	2.689	0.43	0.080005
9	0	-1	-1	3.2366	2.60	3.2366	0.63	6.9807E-6
10	0	1	-1	3.9228	3.97	3.9053	-0.046	0.017535
11	0	-1	1	1.904	1.86	2.0088	0.046	0.10483
12	0	1	1	2.8592	3.49	2.8634	-0.63	0.004208
13	0	0	0	2.5046	2.75	2.7615	-0.24	0.2569
14	0	0	0	2.0084	2.75	2.7615	-0.74	0.7531
15	0	0	0	3.436	2.75	2.7615	0.69	0.6745
16	0	0	0	2.424	2.75	2.7615	-0.32	0.3375
17	0	0	0	3.3612	2.75	2.7615	0.61	0.5997

Table 3a Test of Significance for All Regression Coefficient Term

Source	Sum of squares	df	Mean Square	F-value	p-value
X1	1.16	1	1.16	2.45	0.1617
X2	4.49	1	4.49	9.48	0.0178
X3	0.75	1	0.75	1.58	0.2485
X1X2	0.21	1	0.21	0.43	0.5317
X1X3	0.61	1	0.61	1.28	0.2955
X2X3	0.018	1	0.018	0.038	0.8506
X12	0.014	1	0.014	0.031	0.8662
X22	0.34	1	0.34	0.72	0.4233
X32	0.011	1	0.011	0.024	0.8825

Table 3b Analysis of variance (ANOVA) of regression equation

Source	Sum of squares	df	Mean Square	F-value	p-value
Model	7.59	9	0.84	1.78	0.2298
Residual	3.32	7	0.47		
Lack of fit	1.76	3	0.59	1.50	0.3428
Pure error	1.56	4	0.39	-	-
Cor total	10.91	16	-	-	-

Table 4 Regression Coefficients and the Quadratic Response Surface's Impact

Factor	Coefficient estimate	df	Standard error	95% CI Low	95% CI High	VIF
Intercept	2.75	1	0.31	2.02	3.47	
X1	-0.38	1	0.24	-0.96	0.19	1.00
X2	0.75	1	0.24	0.17	1.32	1.00
X3	-0.31	1	0.24	-0.88	0.27	1.00
X1X2	-0.23	1	0.34	-1.04	0.59	1.00
X1X3	0.39	1	0.34	-0.42	1.20	1.00
X2X3	0.067	1	0.34	-0.75	0.88	1.00
X12	-0.059	1	0.34	-0.85	0.73	1.01
X22	0.29	1	0.34	-0.51	1.08	1.01
X32	-0.051	1	0.34	-0.84	0.74	1.01

Interactive effect of variable factors on Oil Yield

The utilisation of visual representation serves as a mechanism for depicting the correlation between several tiers of experimental variables and their influence on the response, while also emphasising diverse interactions among the variables to ascertain the most favourable conditions.

Figure 3.1 depicts contour and response surface plots, which visually represent the impact of variations in the weight of *C. albidum*, the volume of the solvent, and their interplay on the oil production, while keeping the extraction time constant at zero. This conclusion can be inferred from the outcomes of the plot. Furthermore, it has been observed that the oil yield exhibits an upward trend when the weight of *C. albidum*, measured in grammes, is relatively low and the volume of the solvent is augmented.

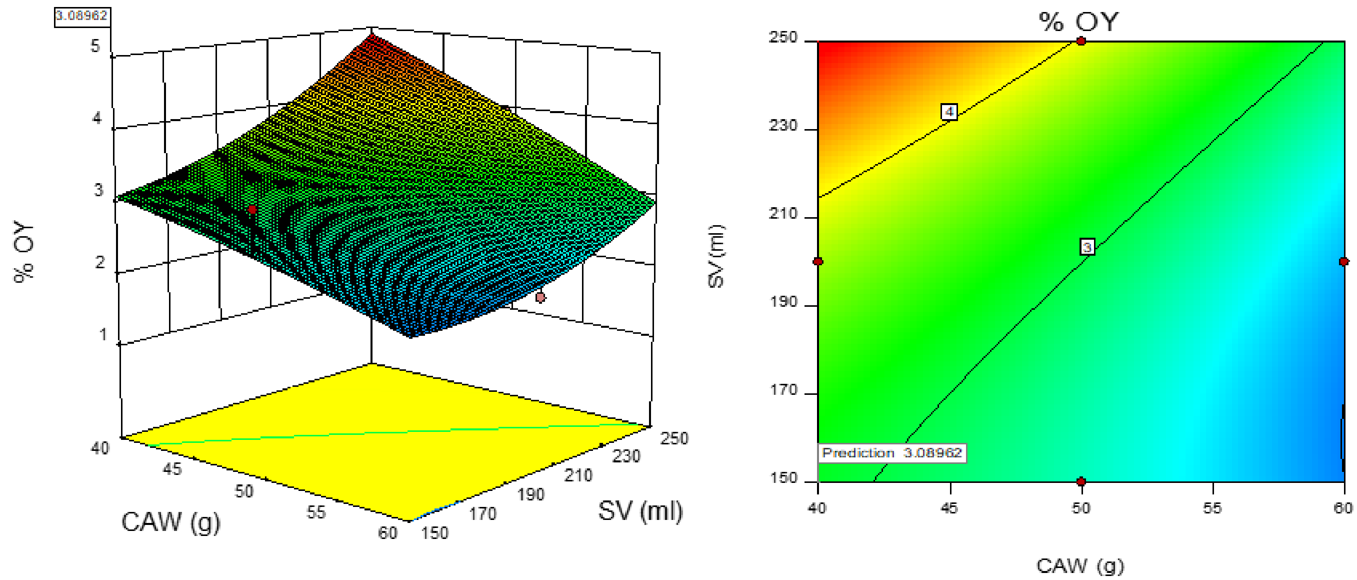


Figure 3.1 The Contour 3D Response Surface Plots for the Effects of *C.albidum* weight (CAW), Solvent volume (SV) and their reciprocating Interaction on Oil Yield keeping Extraction Time (ET) Constant at Zero Level.

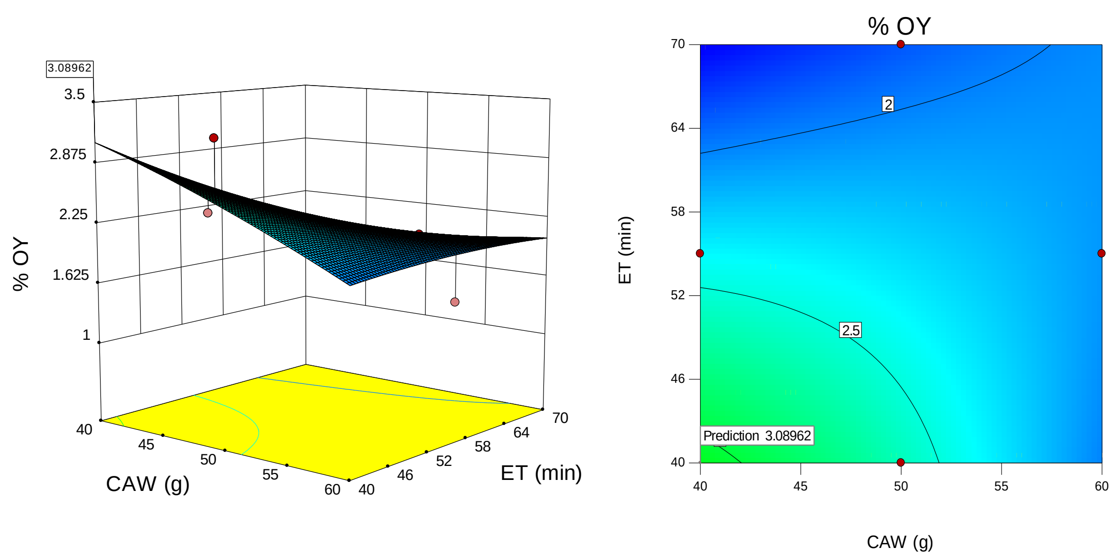


Figure 3.2 The Contour and 3D Response Surface Plots for the Effects of *C. albidum* weight (CAW), Extraction Time (ET) and their reciprocating Interaction on Oil Yield Keeping Solvent volume (SV) Constant at Zero Level.

Figure 3.2 displays contour and 3D response surface plots depicting the effects of *C. albidum* weight, extraction time, and their reciprocal interaction on oil yield, while maintaining the solvent volume at zero. The graph demonstrates that a brief extraction time and a larger solvent volume result in a higher oil yield, surpassing the performance of (Figures 3.1 and 3.2). Employing Neural Power, version 2.5 (CPC-X Software), we investigated the interactions between the process variables for ANN.

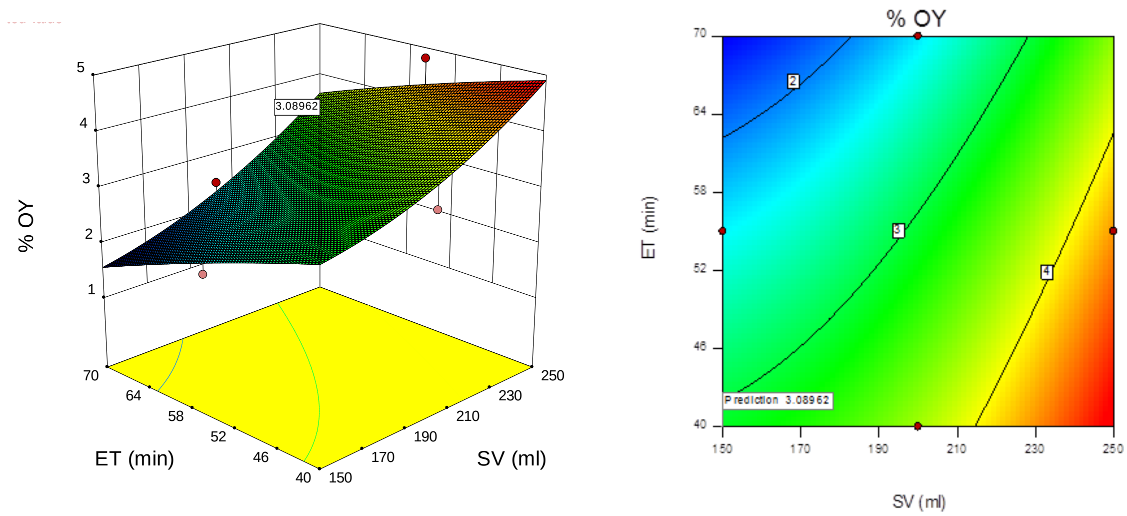


Figure 3.3 The Contour and 3D Response Surface Plots for the Effects of, Extraction Time (ET) and Solvent volume (SV) their reciprocating Interaction on Oil Yield Keeping *C. albidum* weight (CAW) Constant at Zero Level.

In Figure 3.3 and 3.4 we present the relationship between solvent volume, *C. albidum* weight, and oil yield. Figure 3.5 and 3.6 illustrates how the weight of *C. albidum* and the duration of extraction affect the production of *C. albidum* oil. As the extraction time and the amount of solvent used increase, there is a corresponding increase in the oil yield. This interplay between these two factors is also evident in (Figure 3.5). Employing Neural Power, version 2.5 (CPC-X Software), we examined the interactions among the process variables in the context of artificial neural networks (ANN). In Figures 3.5, 3.6, 3.7 & 3.8, you can observe the relationship between solvent volume, *C. albidum* weight, and oil yield

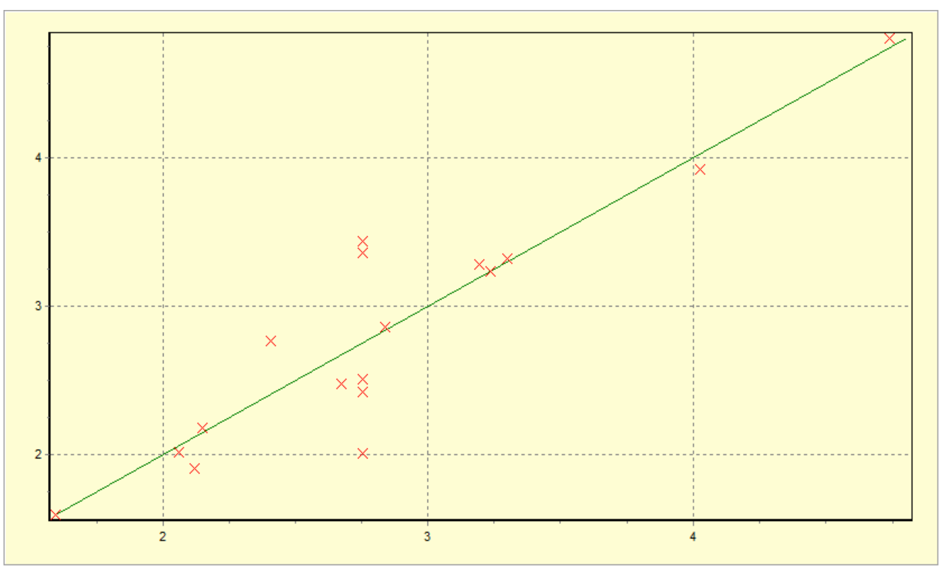
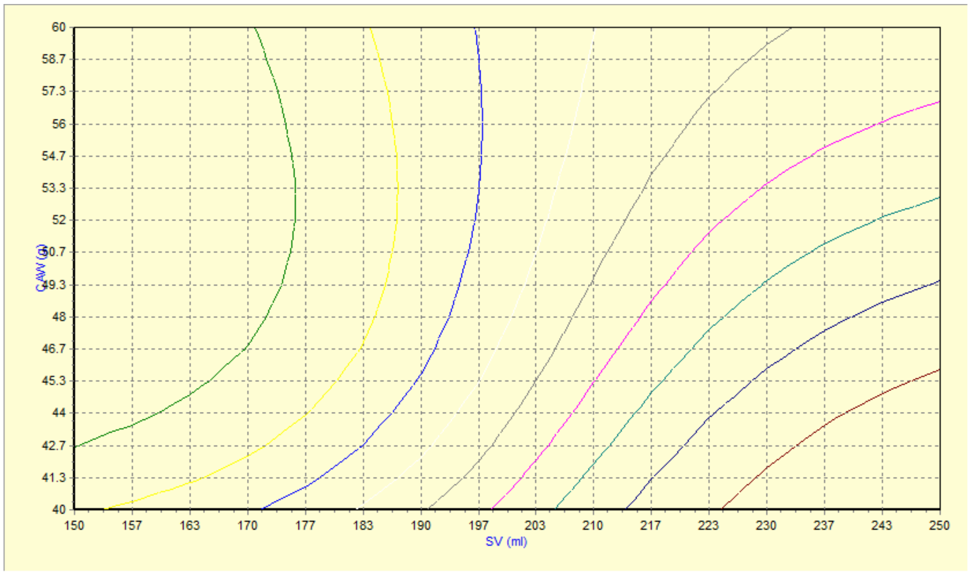


Figure 3.4 Linear Correlation between Experimental Results and ANN Predicted Oil Yield



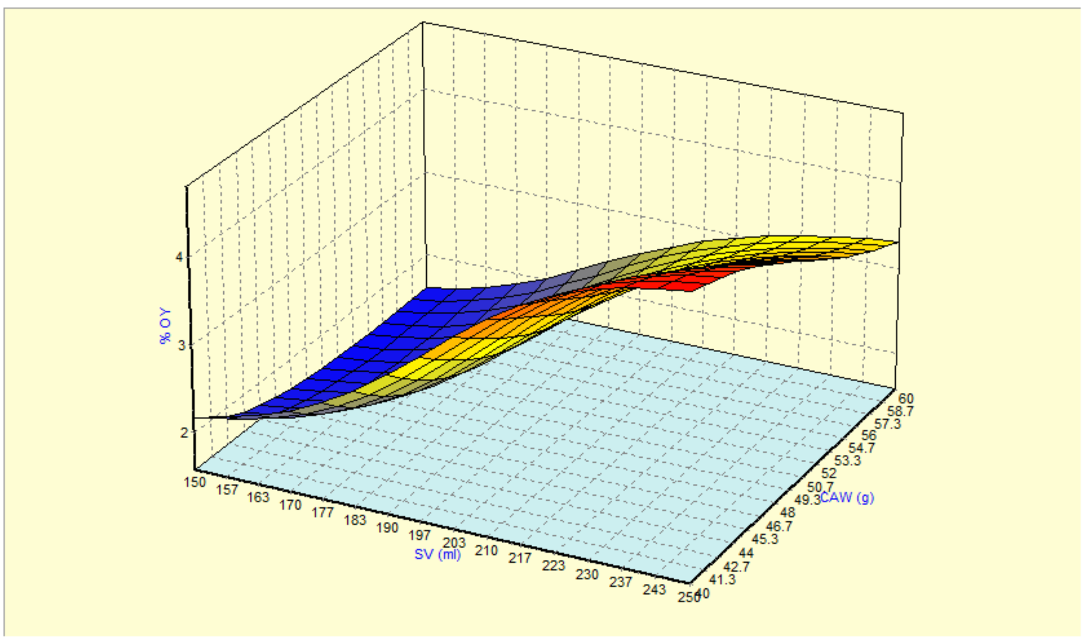


Figure 3.5 3-D plot showing effect of Solvent Volume (SV), *C. albidum* Weight (CAW) and their mutual effect on *Chrysophyllum albidum* oil extraction.

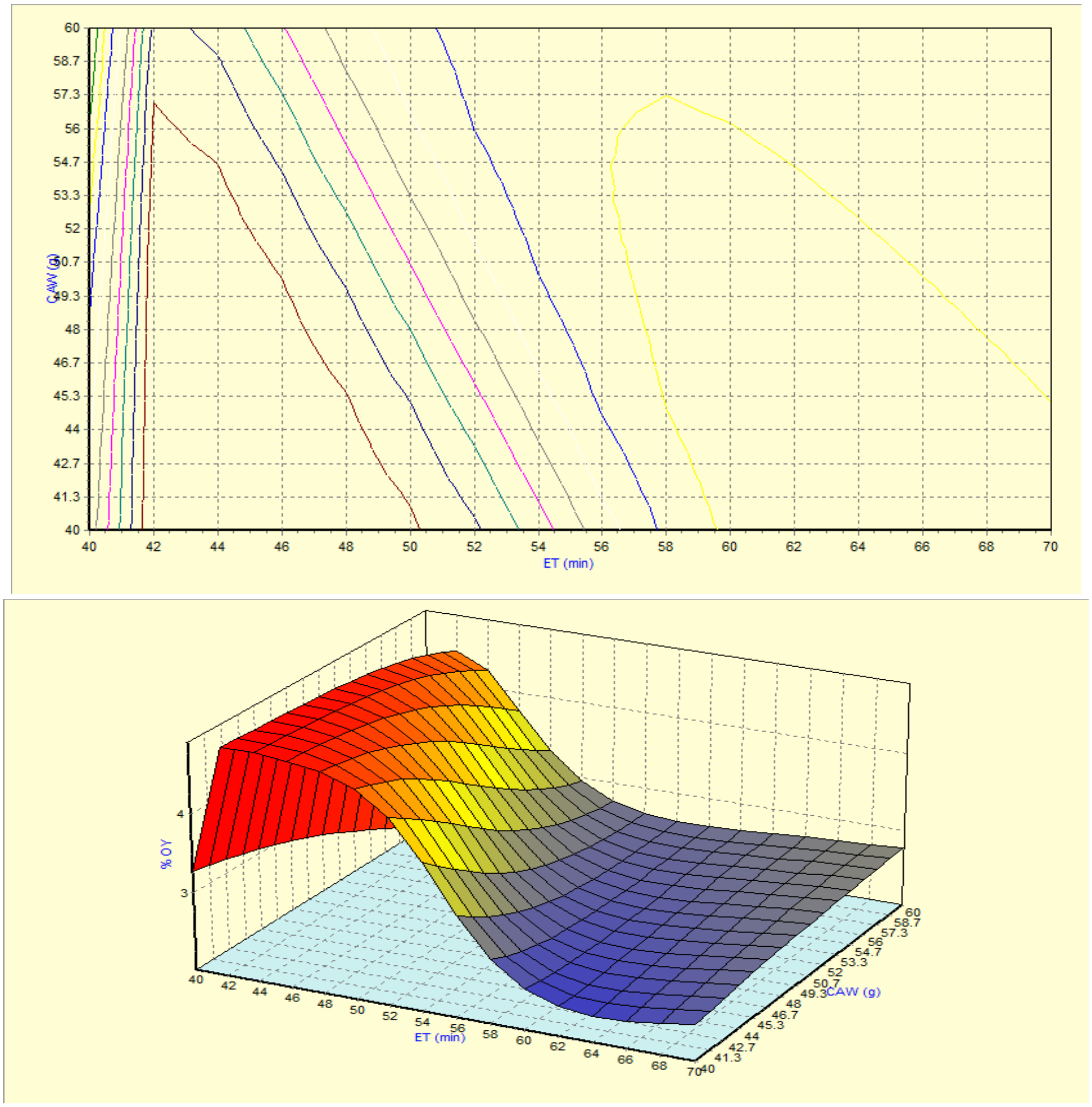


Figure 3.6 3-D plot showing effect of Extraction Time (ET), *C. albidum* Weight (CAW) and their mutual effect on *Chrysophyllum albidum* oil extraction.

Quality Characterization of *Chrysophyllum albidum* (African Star Apple) Seed Oil

Physiochemical properties of Chrysophyllum albidum seed oil

The study encompassed a comprehensive investigation into the physicochemical characteristics of the seed oil of *C. albidum*, which was acquired using the solvent extraction method. The findings are presented in (Table 5). Furthermore, an evaluation was conducted on the fuel characteristics of the aforementioned seed oil. This assessment encompassed many criteria such as cetane number, API, diesel index, and aniline point. The results of this analysis may be found in (Table 6).

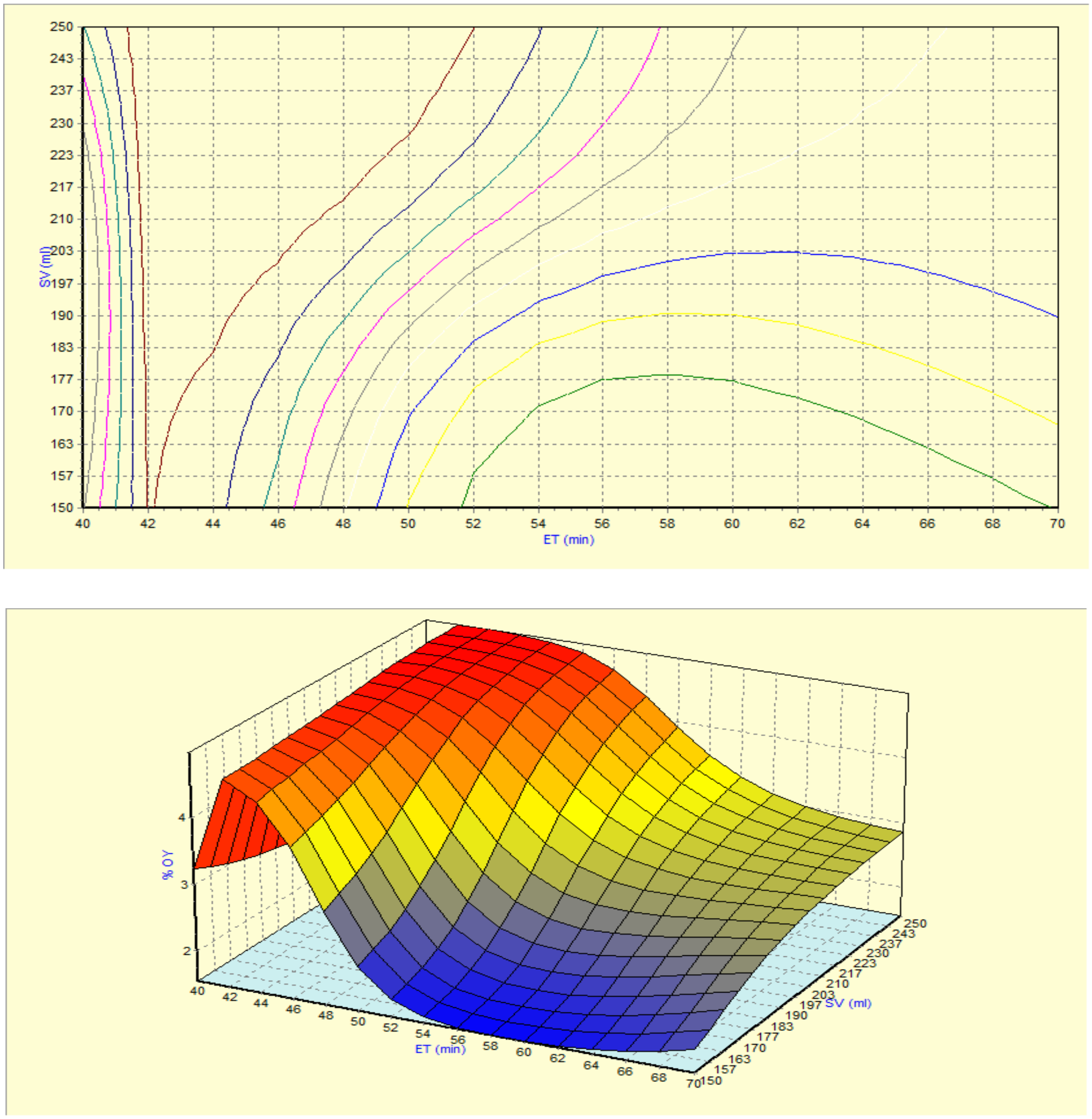


Figure 3.7 3-D plot showing effect of Extraction Time (ET), Solvent Volume (SV), and their mutual effect on *Chrysophyllum albidum* oil extraction.

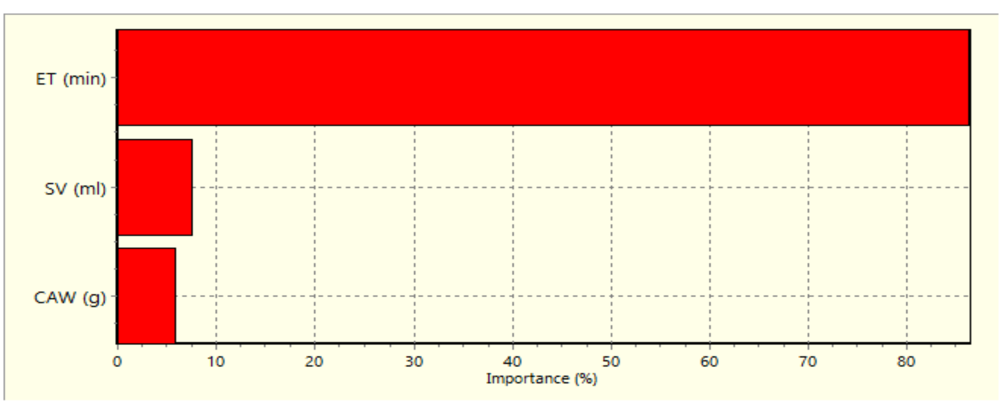


Figure 3.8 Importance of effective parameters on percentage oil yield.

Table 5 Physiochemical and other characteristics of *C. albidum* Seed Oil

Parameters	*C. albidum*
Physical properties	
Physical state at room temperature	Reddish brown
Density (g/ml)	0.91
Moisture content (%)	0.0756
Viscosity (kg/m.s)	8.0805
Specific gravity	0.84
Mean Molecular mass	950.68
Chemical properties	
FFA (as oleic acid)	11.87
Acid value (mg KOH/g oil)	23.74
Saponification value (mg KOH/g oil)	100.98
Iodine value (g I2/100g oil)	87.85
Peroxide value (meq O2/kg oil)	1.34
Higher Heating Value (MJ/kg)	32.11
Fuel properties	
Cetane number	80.58
API	299.95
Diesel index	98.03
Aniline point (oF)	32.68
BPMT	19.18

Table 6 Comparison of Physiochemical Properties with Previous Research Works.

	Adebayo, *et al.*, 2012	Audu, *et al.*, 2019	Amuda, *et al.*, 2013	Omeje, *et al.*, 2019	This Work
Physical properties					
Physical state at room temperature	Deep red	-	Dark brown	Red, yellow, blue, neutral.	Reddish brown
Density (g/ml)	-	-	-	-	0.91
Moisture content (%)	-	-	-	-	0.0756
Viscosity (kg/m.s)	-	1.077	-	-	8.0805
Specific gravity	0.89	0.886	0.92	0.8269	0.84
Mean Molecular mass	-	-	-	-	950.68
Chemical properties					
FFA (as oleic acid)	2.25	1.79	1.26	9.90	11.87
Acid value (mg KOH/g oil)	4.5	2.89	2.52	19.70mg	23.74
Saponification value (mg KOH/g oil)	199.50	193.7	228.4	90.71mg	100.98
Iodine value (g I2/100g oil)	35	33.18	30	163.3mg	87.85
Peroxide value (meq O2/kg oil)	1.57	1.96	1.45	-	1.34

Higher heating value (MJ/kg)	-	-		-	32.11
Fuel properties					
Cetane number	-	-	-	-	80.58
API	-	-	-	-	299.95
Diesel index	-	-	-	-	93.77
Aniline point (oF)	-	-	-	-	32.68
BPMT	-	-	-		19.18

4. CONCLUSIONS

The present study employed Response Surface Methodology (RSM) to identify the ideal values for the independent variables. These variables encompassed a sample weight of 50g, a solvent volume of 250 ml, and an extraction duration of 55 minutes. By utilizing the optimized parameters, the study was able to attain an average oil content of 3.0896% (w/w) via three independent repeats. Nevertheless, a model based on Artificial Neural Network (ANN) made a prediction indicating a greater reaction, with an estimated oil content of 3.9053% (w/w). It is noteworthy to mention that the minimum recorded oil output was 1.5931% (w/w).

Furthermore, the research conducted revealed that the oil derived from the oilseed of C. albidum is not suitable for consumption, although it possesses considerable importance within diverse industrial domains, including the production of soap, personal care items, pharmaceuticals, and cosmetics. Furthermore, the study compared the performance of the ANN model (R2 = 0.9242) and the RSM model (R2 = 0.7000) in terms of modeling and process optimization for oil extraction. Based on the findings of the study, it was observed that the artificial neural network (ANN) model exhibited superior performance compared to the response surface methodology (RSM) model in terms of reaching a higher coefficient of determination (R2). This outcome suggests that the ANN model shown enhanced accuracy and efficacy in its ability to model and optimize the oil extraction process from C. albidum

Declaration

This is a declaration the originality of the manuscript title "Comparative analysis of convensional optimization techniques with Artificial Neural Network (ANN) and Response Surface Methodology (RSM)models for extracting oil from *Chrysophyllum albidum (C. albidum)* seed oil for biodiesel applications" and is not published earlier and have not be submitted for publication elsewhere.

Acknowledgments

The authors acknowledge two anonymous reviewers for their perceptive criticism and beneficial suggestions.

Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Funding

The study has not received any external funding.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES

1. Abel OM, Chinelo AS, Cynthia I, Agbajor GK. Evaluation of African star apple (*chrysophyllum albidum*) seed oil as a potential feedstock for industrial application. Asian J Appl Chem Res 2020; 7(1):31–42. doi: 10.9734/ajacr/2020/v7i130174
2. Adebayo SE, Orhevba BA, Adeoye PA, Fase OJ, Musa JJ. Solvent Extraction and Characterization of oil from African Star Apple (*Chrysophyllum albidum)* seeds. Acad Res Int 2012; 3(2):178-183.
3. Adekanmi DG, Olowofoyeku AE. African star apple: potentials and application of some indigenous species in Nigeria. J Appl Sci Environ Manage 2020; 24(8):1307–1314. doi: 10.4314/jasem.v24i8
4. Adepoju TF, Eyibio UP. Study on oil extraction from *citrullus lanatus (C.Lanatus)* oilseed and its statistical Analysis: A case of Response surface methodology (RSM) and Artificial Neural Network (ANN). Chem Res J 2016; 1(5):28-36.
5. Agunbiade FO, Adewole TA. Methanolysis of Carica papaya seed oil for production of biodiesel. J Fuels 2014; 1–6. doi: 10.1 155/2014/904076
6. Akubugwo IE, Obasi AN, Ginika SC. Nutritional potential of the leaves and seeds of black Nightshade- *Solanum nigrum L. Var virginicum* from Afikpo Nigeria. Pak J Nutr 2007; 6(4):323-326. doi: 10.3923/pjn.2007.323.326
7. Amin SK, Hawash S, Diwani GEl, Rafei SEl. Kinetics and thermodynamics of oil extraction from jatropha curcas in aqueous acidic hexane solutions. J Am Sci 2010; 6(11):293–300.
8. Amuda SO, Edewor TI, Afolabi TJ, Hung YJ. Steam activated carbon prepared from Chrysophyllum albidum seed shell for the adsorption of cadmium in wastewater: Kinetics, equilibrium and thermodynamic studies. Int J Environ Waste Manag 2013; 12(2):213 – 229. doi: 10.1504/IJEWM.2013.055595
9. Amusa NA, Adegbile AA, Muhammed S, Baiyewu RA. Yam Diseases and its Management in Nigeria. Afr J Biotechnol 2003; 2(12):497-502.
10. Audu SS, Beetseh CI, Edward-Ekpu DU, Ewuga AA. Proximate mineral contents and physicochemical properties of *chrysophyllum albium* (African star apple) kernel flour and oil. J Appl Sci Environ Manag 2019; 23(7):1245-1249. doi: 10.4314/jasem.v23i7.9
11. Duyilemi OP, Lawal JO. Anti-bacterial activity and physiochemical screening of *chrysophylum albidum* leaves. Asian J Food Agro-Ind Special issue 2009; S75-S79.
12. Ehiagbonare JE, Onyibe HI, Okoegwale EE. Studies on the isolation of normal and abnormal seedlings of *Chrysophyllum albidium*; A step towards sustainable management of the taxon in the 21st century. Sci Res Essay 2008; 3(12):567–570
13. Emmanuel SA, Adelola OB, Aderemi PA, Jiya JM, Jumoke OF. Solvent extraction and characterization of oil from African star apple (*chrysophyllum albidum*) seeds. Acad Res Int 2012; 3(2):1 78–183.
14. Goziya W, Dzarma A, Chinedu M, Agu A, Nwosu-Obieogua K, Onyedikachi LN, Kalua OA, Ekezie EO, Adiele MC, Chukwulebile AS. Parametric study of oil extraction from African Star Apple (*Chrysophyllum albidum*) seeds. Clean Chem Eng 2022; 2:100018. doi: 10.1016/j.clce.2022.100018
15. Idown O, Aderogba EO, Akinpelu BA, Ogundami AO. Anti-inflammatory and Antioxidant activities of Eleagnine: An alkaloid isolated from *chrysophyllum albidum* seed cotyledons. J Biol Sci 2009; 6(6):1029-1934.
16. Menkiti MC, Agu CM, Udeigwe TK. Extraction of oil from Terminalia catappa L.: process parameter impacts, kinetics, and thermodynamics. Ind Crops Prod 2015; 77:713– 723. doi: 10.1016/j.indcrop.2015.08.019
17. Nwabanne JT. Kinetics and thermodynamics study of oil extraction from fluted pumpkin seed. Int J Multidiscip Sci Eng 2012; 3(6):11–15.
18. Olakunle MS, Umar IS. Extraction of Moringa Seed Oil: Kinetics and Thermodynamic Studies. FUW Trends Sci Technol J 2019; 4(1):48 –53
19. Omeje KO, Iroha OK, Edeke AA, Omeje HC, Apeh VO. Characterization and fatty acid profile analysis of oil extracted from unexploited seed of African star apple (Udara). OCL 2019; 26(10). doi: 10.1051/ocl/2019007
20. Oyeniran OO, Taiwo AE, Betiku E. A Modeling Study by Response Surface Methodology on the culture parameters Optimization of Citric Acid Bio production from sweet potato peel. Ife J Technol 2013; 22(1):21-25.
21. Patel VR, Dumancas GG, Kasi Viswanath LC, Maples R, Subong BJ. Castor Oil: Properties, Uses, and Optimization of Processing Parameters in Commercial Production. Lipid Insights 2016; 9:1-12. doi: 10.4137/LPI.S40233
22. Santos SBD, Martins MA, Caneschi AL, Aguilar PRM, Coimbra JSDR. Kinetics and thermodynamics of oil extraction from jatropha curcas L. Using ethanol as a solvent. Int J Chem Eng 2015. doi: 10.1155/2015/871236